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## Watershed Characterization Using DEM-Derived Parameters in Neem ka Thana, Sikar District, Rajasthan, India

Mr. Santosh Kumar, Dr. Mahesh Kumar

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DOI : <https://doi.org/10.5281/zenodo.17326157>

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### ARTICLE DETAILS

**Research Paper**

**Accepted:** 25-09-2025

**Published:** 10-10-2025

**Keywords:**

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### ABSTRACT

Watershed delineation plays a crucial role in understanding surface hydrology, managing water resources, and implementing sustainable land management practices (Strahler, 1957; Maidment, 2002). This study focuses on the hydrological characterization and delineation of the watershed boundary in the Neem ka Thana region of Sikar district, Rajasthan, using geospatial techniques in QGIS. A 30 m resolution CARTO-DEM was utilized for deriving terrain parameters, including slope, aspect, flow direction, and flow accumulation, followed by the extraction of the stream network and watershed boundaries (Bhuvan). Sink-filling techniques were applied to eliminate depressions in the DEM and ensure accurate hydrological connectivity (Jenson & Domingue, 1988). The results reveal the spatial distribution of slopes, drainage patterns, and sub-watershed boundaries, which are critical for identifying potential groundwater recharge zones, erosion-prone areas, and surface runoff pathways (Patel et al., 2012). This study demonstrates the efficiency of GIS-based methods in watershed analysis, offering a cost-effective and scalable approach for semi-arid regions such as Rajasthan, where water scarcity and soil erosion present major environmental challenges (CGWB, 2024). The methodology and results can serve as a scientific foundation for integrated water resource management, planning rainwater harvesting structures, and mitigating the impacts of land degradation.

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## 1. Introduction

In arid and semi-arid regions, such as Rajasthan, India, the efficient management of water resources is a pressing need due to erratic rainfall, high evapotranspiration rates, and increasing demands from the agricultural, domestic, and industrial sectors (CGWB, 2024). Watersheds — natural hydrological units that drain precipitation through a common outlet — serve as the basis for managing surface and subsurface water resources effectively (Strahler, 1957).

Watershed delineation, supported by Geographic Information Systems (GIS) and Digital Elevation Models (DEMs), enables accurate mapping of drainage networks, slope gradients, flow accumulation zones, and catchment boundaries (Jenson & Domingue, 1988). Such analysis not only provides an understanding of hydrological behaviour but also supports decision-making in water harvesting, groundwater recharge planning, soil conservation, and disaster risk reduction (Patel et al., 2012).

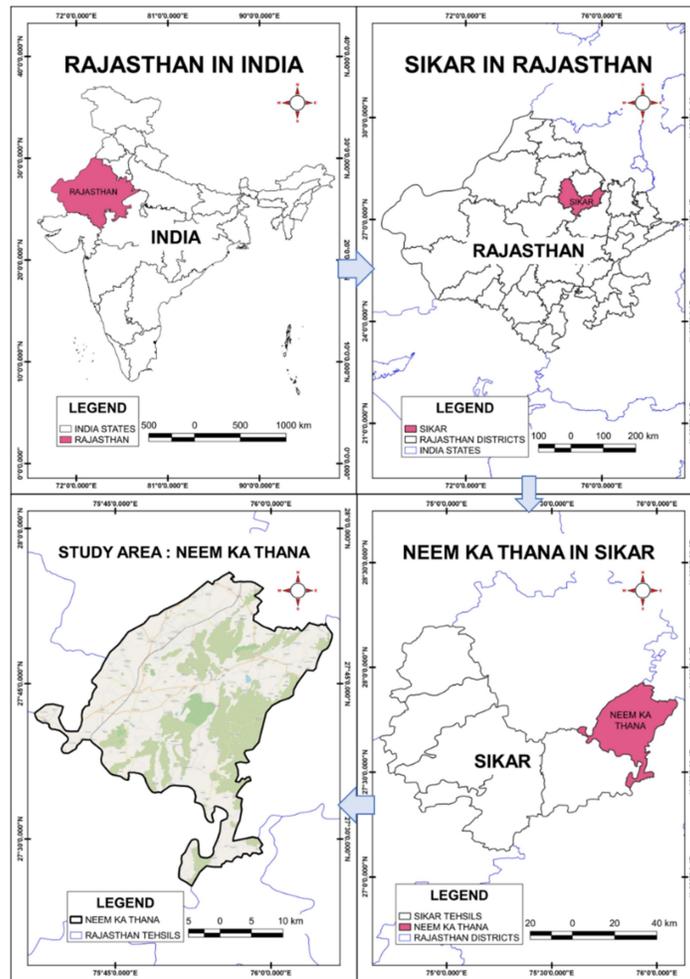
This study aims to delineate the watershed and analyse key hydrological parameters of the Neem ka Thana region using CARTO-DEM and QGIS. By deriving slope, aspect, flow direction, and stream networks, the research identifies areas of hydrological significance that can be leveraged for sustainable water management. The methodology presented here is replicable and adaptable for similar semi-arid landscapes, offering valuable insights for planners, conservationists, and local authorities.

## 2. Study Area

Neem Ka Thana is a city and tehsil in **Sikar District, Rajasthan**, formerly elevated to district status in 2023 before being re-integrated in 2024 (Wikipedia). The area lies between coordinates **27.759875°N, 75.770347°E** (northwest) and **27.716509°N, 75.829854°E** (southeast). At an elevation of approximately 446 m, it is part of the Shekhawati region, characterized by undulating terrain and semi-arid climate (Wikipedia). Annual rainfall averages around 450–500 mm, mostly during the summer monsoon, contributing to hydrological variability and groundwater stress levels (CGWB, 2024).

The region's biological significance and significant land-use dynamics are reflected in notable features such as the adjacent Bansiyal–Khetri Conservation Reserve (≈70 km<sup>2</sup>) and Baleshwar Conservation Reserve (≈221 km<sup>2</sup>) (Forest Department Rajasthan, 2024; RajRAS, 2024; Rajasthan Tourism, 2024). These reserves, along with agricultural and scrubland areas, shape the watershed's hydrological and ecological interactions.

The Neem ka Thana region in Sikar district, Rajasthan, is characterized by undulating terrain, seasonal streams, and highly variable rainfall patterns (*Wikipedia*). These conditions make it prone to both water scarcity and flash flooding during monsoon events. Traditional field surveys for watershed mapping are time-consuming and labour-intensive, whereas GIS-based approaches provide rapid, precise, and reproducible results using freely available elevation datasets (*IJRASET, AGWA*).



### 3. Methodology

The methodology adopted for this study integrates Digital Elevation Model (DEM) processing, hydrological analysis, and watershed delineation using QGIS. The workflow involves multiple sequential steps, each serving a specific purpose in deriving accurate hydrological parameters. The figure below presents the flowchart of the methodology.



### 3.1 Data Acquisition and DEM Preprocessing

A high-resolution DEM was used as the primary input. Sink filling was applied to remove spurious depressions to ensure accurate flow routing.

### 3.2 Derivation of Thematic Layers

Elevation Map: Classified elevation zones highlight relief variation.

Slope Map: Generated in degrees to assess runoff potential.

Aspect Map: Categorized into eight primary directions and flat zones to understand slope orientation

Flow Direction Map: Derived using the D8 algorithm to determine water movement pathways.

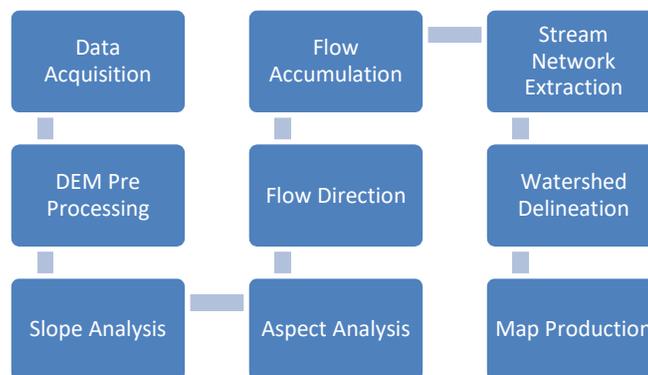
Flow Accumulation Map: Computed to identify potential stream initiation points and drainage concentration zones.

River Network Map: Extracted by applying a threshold to the flow accumulation raster, delineating the stream order.

Watershed Boundary Map: Final watershed extent generated using pour point and flow direction data.

### 3.3 Interpretation Approach

Each thematic map was visually inspected and interpreted to understand its role in watershed hydrology, particularly regarding water movement, erosion susceptibility, and planning interventions.





## 4. Results and Discussion

### 4.1 Elevation

The study area's elevation varies from moderate hill slopes to low-lying plains. The northwest is home to the majority of the higher elevations, which progressively drop towards the southeast. Higher areas contribute to faster runoff and a higher risk of erosion. These gradients affect the direction of surface water flow and stream gradient (*Jenson & Domingue, 1988; Strahler, 1957*).

### 4.2 Slope

The majority of the watershed has gentle slopes (0–5°), according to the slope study, which suggests that it is suitable for agriculture and has a low runoff velocity. Only hilly areas have steeper slopes (>15°); thus, in order to stop erosion, soil conservation measures are necessary (*Patel et al., 2012; Wilson & Gallant, 2000*).

### 4.3 Aspect

The aspect map shows a dominance of south and south-west facing slopes, which receive higher solar radiation, influencing evapotranspiration rates and soil moisture retention. North-facing slopes have relatively cooler microclimates, potentially supporting different vegetation patterns (*Wilson et al., 2007*).

### 4.4 Flow Direction

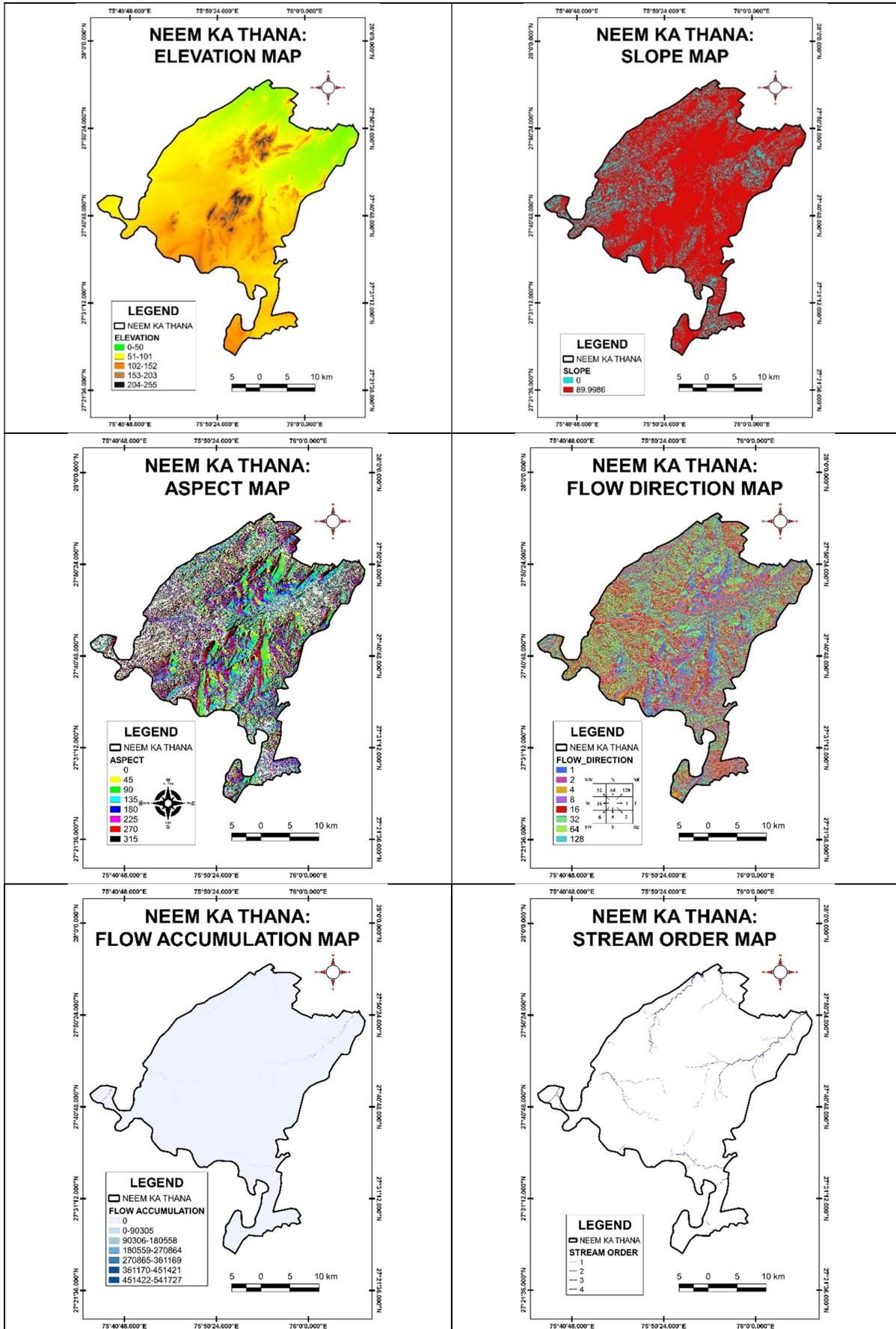
Flow direction analysis indicates a general south-eastward drainage pattern, consistent with the elevation gradient. Minor deviations occur in localized depressions and hilly regions, creating sub-catchments and influencing stream junctions (*Jenson & Domingue, 1988*).

### 4.5 Flow Accumulation

High flow accumulation zones correspond to main channel locations and confluence points. These areas are key for groundwater recharge structures such as check dams and percolation tanks. The map also identifies potential sites for floodwater storage (*Maidment, 2002*).

### 4.6 Stream Network

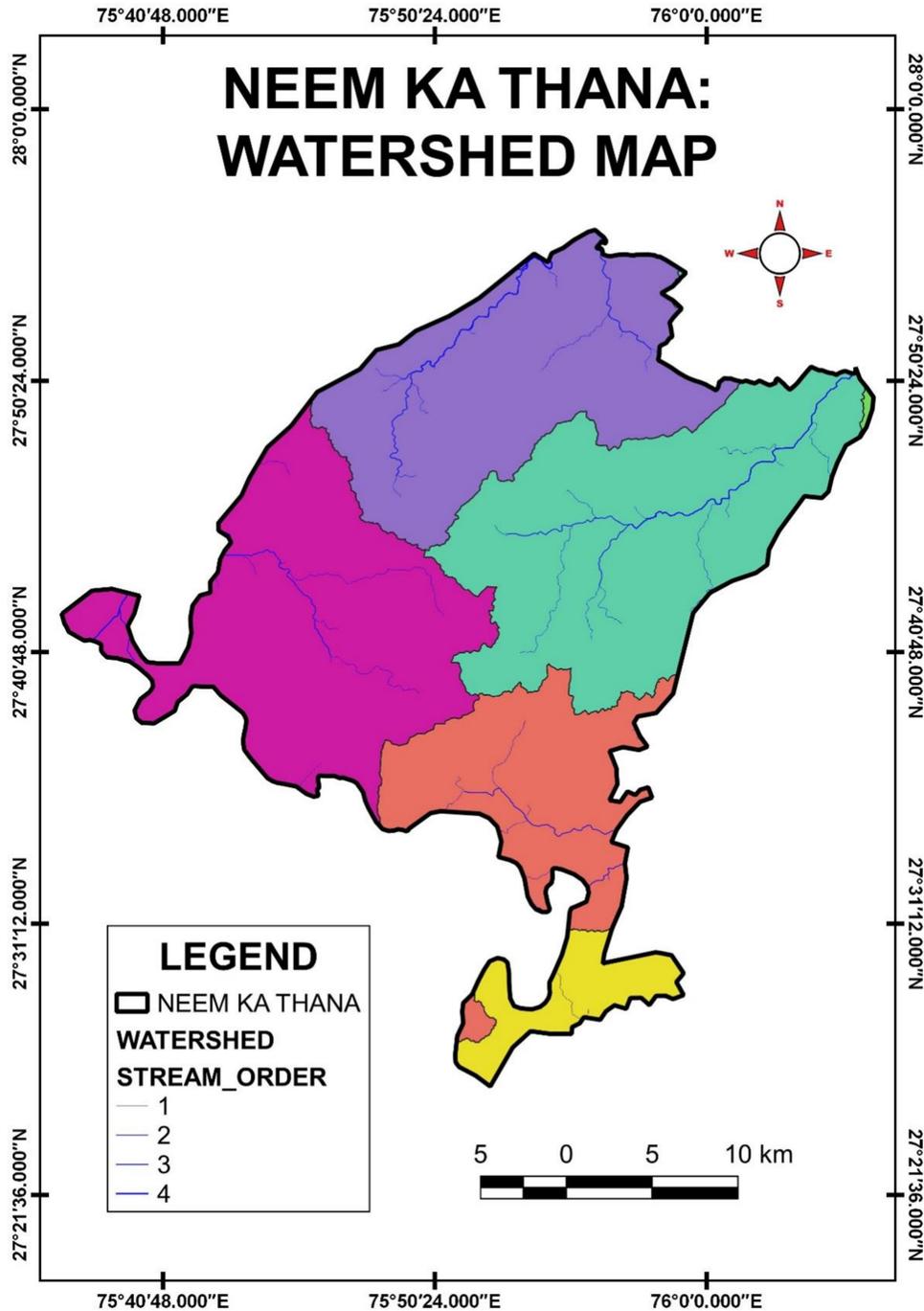
The extracted river/stream network displays a dendritic drainage pattern, typical of regions with homogeneous lithology. First- and second-order streams dominate, highlighting numerous small tributaries feeding into the main channel (*Strahler, 1957*).





### 4.7 Watershed Boundary

The delineated watershed boundary defines the complete hydrological area draining towards the main outlet in Neem Ka Thana. It captures all contributing runoff zones and is essential for understanding surface water flow, sediment movement, and recharge potential (Strahler, 1957). This boundary serves as the base unit for planning and implementing watershed management measures, ensuring interventions align with natural drainage patterns. It also provides a framework for accurate runoff estimation and erosion control planning.





## 5. Discussion

The integration of topographic and hydrological parameters derived from CARTO DEM, including slope, aspect, flow direction, flow accumulation, and watershed delineation, provided an effective framework for identifying potential groundwater zones in Neem Ka Thana (*Bhuvan, 2025; Jenson & Domingue, 1988*).

The slope map revealed that areas with gentle slopes ( $<5^\circ$ ) are more favourable for groundwater infiltration, as runoff velocity is reduced, allowing water to percolate into the subsurface (*Patel et al., 2012; Wilson & Gallant, 2000*). Conversely, steep slopes ( $>15^\circ$ ) promote rapid surface runoff, reducing recharge potential. Aspect analysis indicated that north- and northeast-facing slopes retain relatively higher soil moisture due to reduced solar exposure, enhancing recharge prospects (*Wilson et al., 2007*).

Flow accumulation patterns identified primary drainage channels and depressions that act as natural groundwater recharge sites (*Maidment, 2002*). The flow direction map confirmed the hydrological network's alignment with natural drainage, validating the watershed extraction process. Comparison with river data from Bhuvan further confirmed the accuracy of the delineated watershed boundaries.

Overall, the combined spatial analysis highlights the interplay between terrain characteristics and hydrological processes in determining recharge potential. Combining DEM-derived terrain metrics within a GIS supports robust delineation of likely groundwater recharge zones, which is essential for sustainable water resource management in semi-arid regions like Neem Ka Thana (*CGWB, 2024*).

## 6. Conclusion

This study demonstrates the applicability of GIS and remote sensing techniques in delineating groundwater potential zones in semi-arid terrains (*Patel et al., 2012; CGWB, 2024*). By integrating DEM-derived parameters—slope, aspect, flow direction, flow accumulation, and watershed boundaries—it is possible to identify areas with higher groundwater recharge potential (*Jenson & Domingue, 1988; Maidment, 2002*).

The findings indicate that gentle slopes, favourable aspects, and high flow accumulation areas are key indicators of groundwater-rich zones (*Wilson & Gallant, 2000*). The validated watershed boundaries further improve the reliability of the spatial analysis (*Strahler, 1957*).



Such GIS-based assessments can serve as a decision-support tool for local authorities, enabling targeted groundwater recharge interventions, well site selection, and sustainable water management strategies in Rajasthan's drought-prone districts (CGWB, 2024). Future studies can incorporate rainfall, land use/land cover, and soil permeability data to enhance the precision of the groundwater potential mapping (Wilson et al., 2007).

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